Working with Polygons and Controlling Slopes in the MineSight® 3-D Pit Expansion Tool

In the Mine Planning cycle it is important to use open pit designs that reflect the mining process. This can be done within the **Pit Expansion** tool which allows you to create accurate mining pits by defining various design options such as **Face slope**(s), **Pit slope**(s), and **Berm width**(s) through the use of input tables and 3D block model values. This article will cover these options, as well as tips for generating a successful pit expansion.

Redefine Polygon Direction after Splicing Pit Toe or Crest

When creating a pit design using the **Pit Expansion** tool, bench polygons are created which outline the shape of the pit, typically on each mining bench toe or mid-bench elevation. Each polygon has a specific direction: either clockwise or counter-clockwise, depending upon the parameters that were used during the setup of the tool, such as expanding Up/Down and Inward/Outward. While this may seem like a minor detail, it is actually very important to the proper operation of the tool.

Sometimes it's beneficial to use the **Polyline | Splice** function to edit the toe and crest polygons of the pit as it expands. This allows you to change the shape of the pit during the expansion. Following the splice, you can then expand the pit in the desired direction and the pit will continue from the spliced toe.

However, when you manually splice the crest or toe polygons, it is possible splicing will reverse the direction of the polygons. This will cause an outward expansion to turn inward or an inward expansion to turn outward. See Figure 1 below for an example of this behavior.

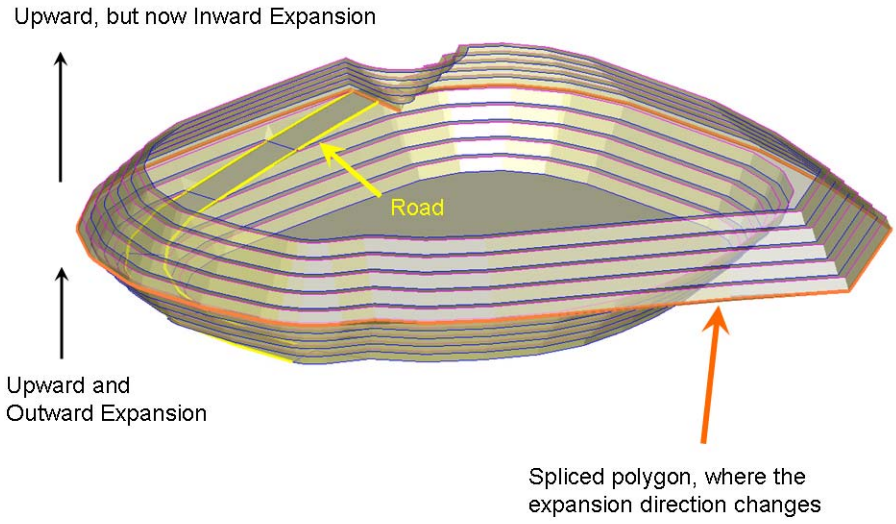

Figure 1. An "Up and Outward" pit expansion incorrectly turns inward on itself following the splicing of a Pit Toe polygon.

This issue can be resolved by manually redefining the polygon direction. On the **Expansion** tab, click the **Edit Strings** button. Toggle the appropriate **Toes** or **Crests** edit option and the desired **At level** elevation (Figure 2). Click **OK** to add the polygon to the **Selection Set** so the polygon can be operated on by MS3D CAD functions.

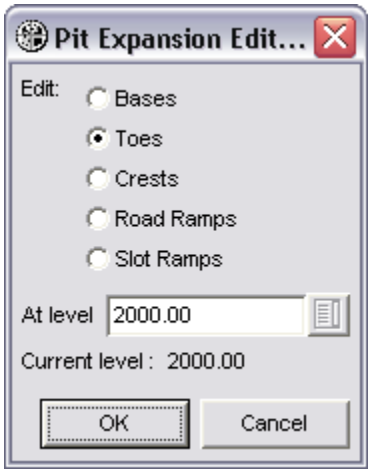

Figure 2. **Edit Strings** *dialog in the* **Pit Expansion** *tool.*

Next, go to the MineSight® 3-D (MS3D) **Polyline** menu and select **Redefine | Direction**. Toggle **Show current polyline/polygon directions** and specify an **Arrow Size** to view the current direction (Figure 3). Next, toggle **Polygons** and choose the appropriate direction. Click **Apply** and the polygon direction will be corrected. Once this is done, save the polygon. Expansion of the pit can be continued as normal. This is shown in Figure 4 below.

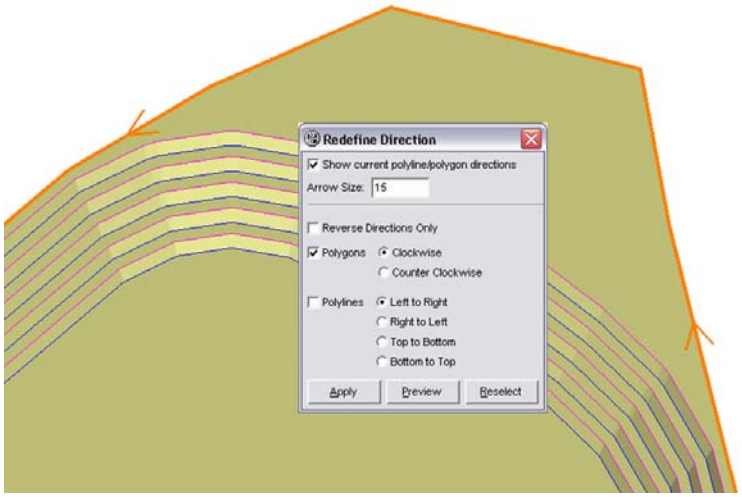

Figure 3. The **Redefine Direction** *function showing the spliced polygon going counter-clockwise. Use the dialog options to change the direction to clockwise.*

HINT: For expansions in the shape of a pit (Outward and Up or Inward and Down), lines should maintain a clockwise direction. For expansions in the shape of a dump (Inward and Up or Outward and Down), lines should maintain a counter-clockwise direction.

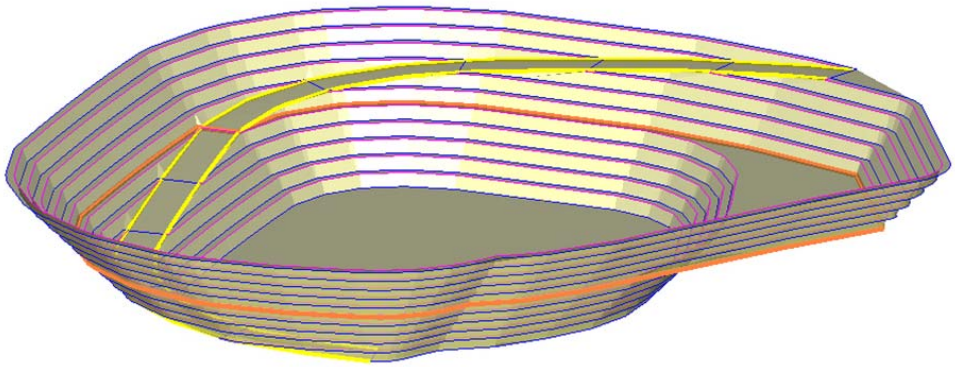

Figure 4. Pit expansion after redefining the polygon direction.

Controlling Pit Expansion with Face slope, Pit slope, and Berm width Parameters

On the **Required** tab of the **Pit Expansion** tool, you can define several parameters that control the expansion characteristics of a pit. We will focus on **Face slope**, **Pit slope**, and **Berm width** as illustrated in Figure 5. The **Face slope** parameter is used to specify the slope of the bench faces. The **Pit slope** parameter is used to specify the overall **Pit slope** defined by an imaginary line extending between two toe or crest polygons. The **Berm width** parameter is used to specify the desired bench width.

During the creation of a pit design, the **Pit Expansion** tool will honor two of these three variables. The **Face slope** value will always be honored and is used in conjunction with either the **Pit slope** or the **Berm width** to determine the overall slope angle of the expansion.

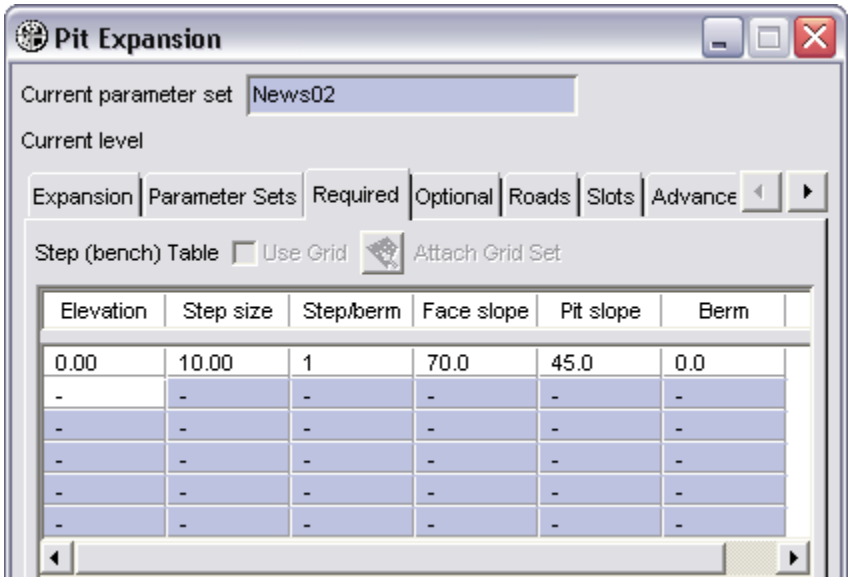

Figure 5. Options for controlling the overall slope of the pit design.

In all cases, the minimum overall slope angle as prescribed by the **Face slope** and **Pit slope** or the **Face slope** and **Berm width** will be used. Because of this, the **Pit slope** value entered can be thought of as a "maximum" overall slope angle, while the **Berm width** can be thought of as a minimum **Berm width**.

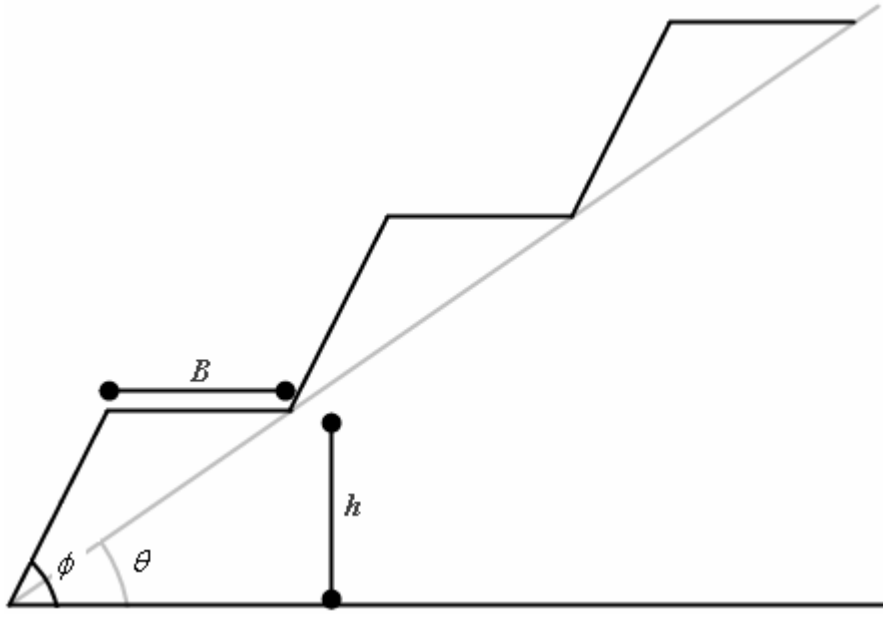

Figure 6. Mathematical definitions for variables defined on the **Required** *tab in the* **Pit Expansion** *tool. B =* **Berm width**, *h =* **Step size** *(default is the bench height),* θ *=* **Pit slope**, ϕ *=* **Face slope**.

In a case where the pit expansion shape is determined by the **Face slope** and **Pit slope**, the **Berm width** will be calculated using the following formula:

$$B = h * \left(\frac{1}{\tan\theta} - \frac{1}{\tan\phi} \right)$$

Because the **Berm width** value is treated as a "minimum" **Berm width**, if the **Berm width** entered in the table is greater than the value calculated from this formula, the pit will expand using **Berm width** instead of **Pit slope**.

In the case where the pit expansion shape is determined by the **Face slope** and **Berm width**, the **Pit slope** angle will be calculated using the following formula:

$$\theta = \tan^{-1}\left(\frac{h}{B + h/\tan\phi} \right)$$

Because the **Pit slope** value is treated as a "maximum" **Pit slope**, if the **Pit slope** value entered into the table is less than the number calculated from this formula, the pit will expand using **Pit slope** instead of **Berm width**.

If you wish to use one of these methods specifically over the other, do the following:

Using Face slope and Pit slope
To expand your pit using the **Face slope** while honoring the **Pit slope**, enter a "0" for the **Berm width** for all levels. This will negate any effect this entry has on the calculation. This ensures that the **Face slope** and **Pit slope** calculation method is always followed.

Using Face slope and Berm width
To expand your pit design using the **Face slope** while honoring the **Berm width**, enter a **Pit slope** equal to the **Face slope** for all levels. This ensures that the expansion will never produce an overall slope that is lower than the **Face slope** with **Pit slope** method, thereby ensuring that the **Face slope** with **Berm width** method is followed.

Defining Pit Expansion Parameters by Sector table, Model value, or Model/code table

An alternative to using the **Step (bench) table** for specifying the **Face slope**, **Pit slope**, and **Berm width** values is to use the **Optional** tab where slope and berm values can be retrieved from either a **Sector table**, a **Model value**, or **Model/code table** (see Figure 7). To use the **Model value** and **Model/code table** options, you must select a 3D block model view using the model view selector .

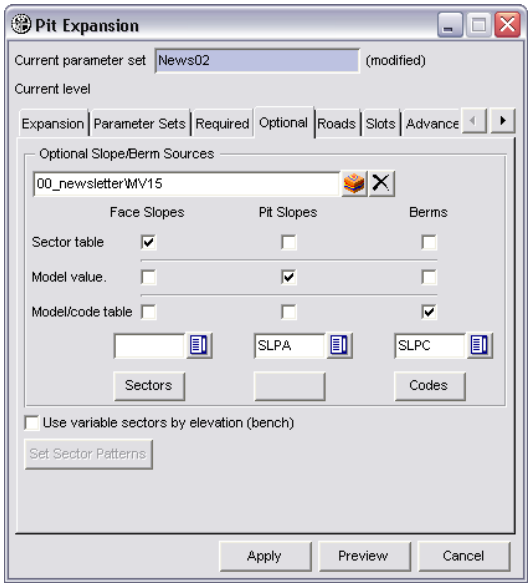

Figure 7. More flexibility in the **Face slope**, **Pit slope**, *and* **Berm width** *value is available through the* **Optional** *tab of the* **Pit Expansion** *tool.*

Sector table

The **Sector table** option allows you to manually enter **Face slope**, **Pit slope**, and **Berm width** values based upon an azimuth range. To use this option, for one or more of these parameters, toggle **Sector table** for the desired parameter, **Face slope**s in this example. Notice the corresponding **Sectors** button is enabled as shown in Figure 7.

Click the **Sectors** button  to open the sector editing dialog (Figure 8).

Within the **Sector** dialog, the center for the sectors must be specified. The center can be defined either by digitizing directly in the viewer using the **Digitize** button  or by entering the East and North coordinates manually.

In the table, the value for the parameter (**Face slope** in our example) is specified as a function of azimuth. The sectors are defined by the first azimuth that is part of the given sector. Thus, in Figure 8 below, the sector corresponding to 0-45 degrees is assigned the **Face slope** corresponding to azimuth equal to zero, 70 degrees in this example. Continue through all of the sectors around the pit in this manner. By toggling the **Show center** and **Show rays** options, you can visually check the sectors as they are entered into the table as shown below in Figure 8. The sectors have been labeled to demonstrate their corresponding **Face slope**(s).

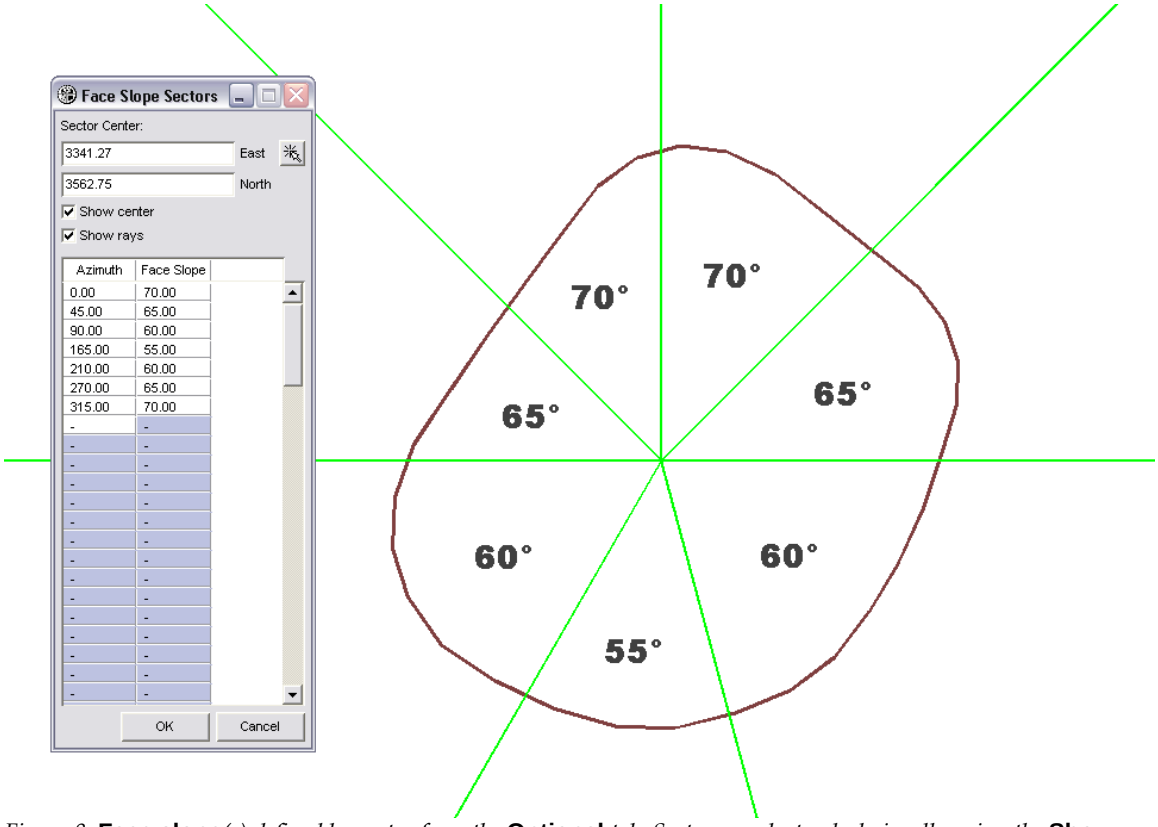

Figure 8. **Face slope***(s) defined by sector from the* **Optional** *tab. Sectors can be tracked visually using the* **Show Center** *and* **Show Rays** *options.*

Model Value

The **Face slope**, **Pit slope**, and **Berm width** can be defined by reading item data from a 3D block model. To utilize this option, select a model view which references the appropriate 3D block model. Next, toggle **Model value** under the desired parameter and select the item containing the data using the item chooser (**Pit slope** defined using item SLPA in the example in Figure 7). Pit expansion may now start/continue utilizing the block model data.

Model/code Table

The **Model/code table** is used to define parameter values based on value for one code item in the 3D block model. To use this option, select a model view which references the appropriate 3D block model. Toggle **Model/code table** for the desired parameter, then select the code item using the item chooser (**Berm width** defined using item SLPC in the example in Figure 7). The **Codes** button at the bottom of the panel is enabled.

Click the **Codes** button and enter valid code values and respective parameter values to be used as shown in Figure 9. Click **OK** when finished.

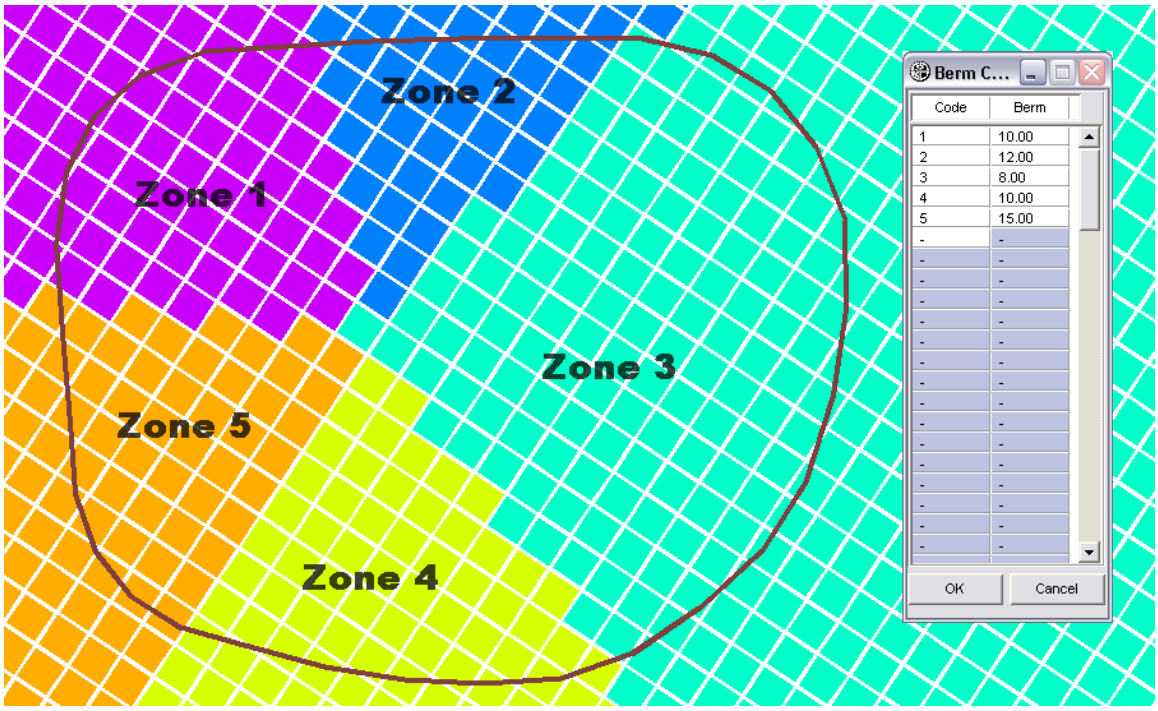

Figure 9. View of the Pit Expansion "Base" polygon above various 3D block model slope zones. To the right, the code table matches the zones with corresponding **Berm width***s.*

The **Pit Expansion** tool will use the parameter values entered on the **Optional** tab first. If the parameter is not defined there, it will use the values entered in the **Step (bench) table**. However, the same rules discussed in the **Controlling Pit Expansion…** section of this article still apply. The **Pit slope** value entered in the **Step (bench) table** will still act as a maximum **Pit slope**, introducing the possibility that the **Berm width** values from the model will be ignored in certain cases.

Consider the following examples.

Figure 10 shows the pit using the varying **Berm width** values as entered into the code table in Figure 9. The **Face slope** (70 degrees) and the **Pit slope** (maximum of 45 degrees) are entered in the **Step (bench) table** as shown in Figure 5. In this case, the **Face slope** with **Berm width** expansion never results in a **Pit slope** greater than 45 degrees, rendering the **Pit slope** value irrelevant.

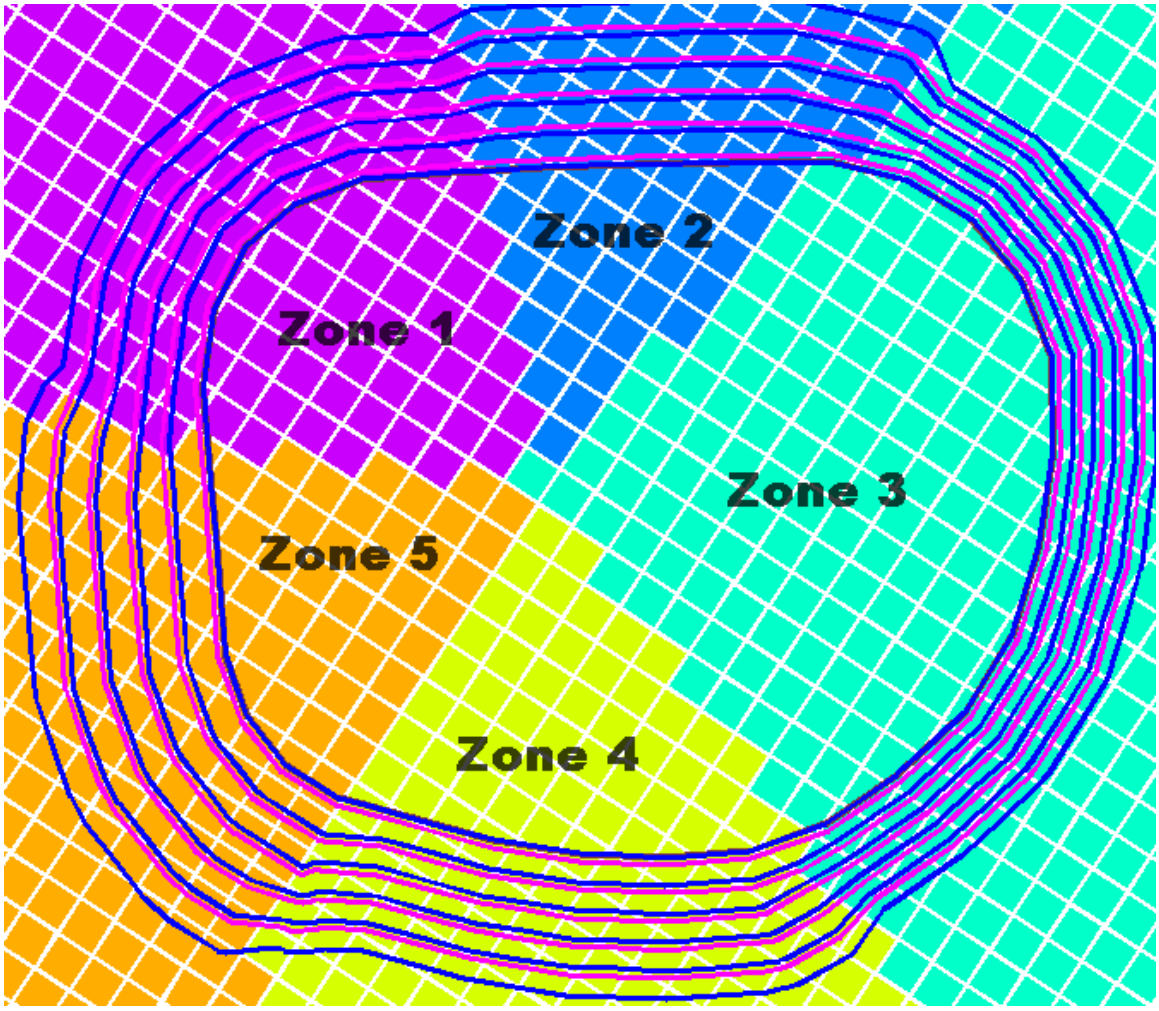

Figure 10. Contours representing varying **Berm width** *(Figure 9) with* **Face slope**=*70 degrees and the* **Pit slope**=*(maximum) 45 degrees (Figure 5) resulting in a* **Face slope** *and* **Berm width** *expansion.*

Now, use the exact same configuration as above, except change the **Pit slope** value in the **Step (bench) table** in Figure 5 from 45 to 25 degrees. The **Pit slope** calculated using the **Face slope** with berm method exceeds 25 degrees for all **Berm width**(s). Thus, this pit expands using the **Face slope** with **Pit slope** method and the expansion has a uniform **Pit slope** of 25 degrees in all directions as shown in Figure 11.

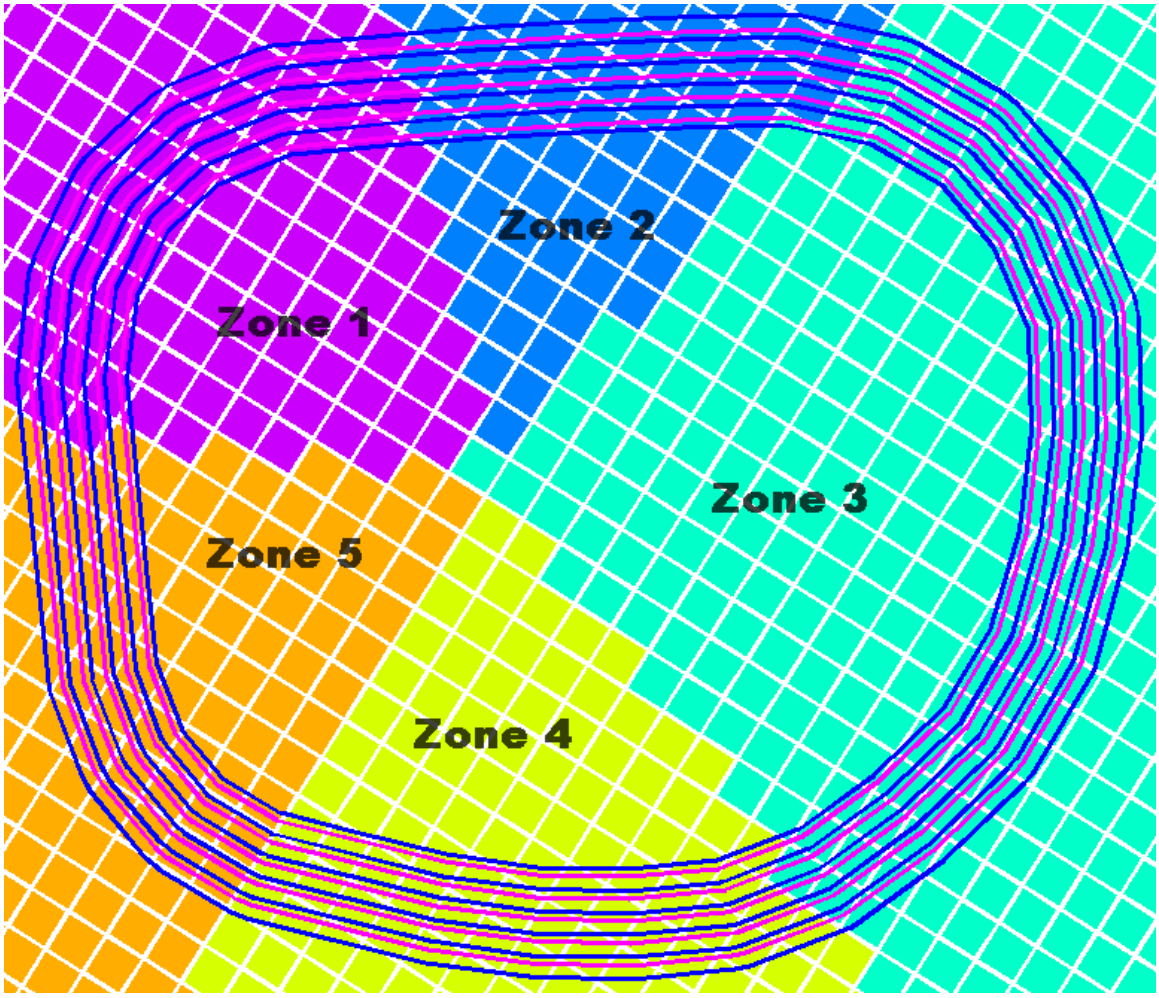

Figure 11. Contours representing varying **Berm width** *(Figure 9) with* **Face slope***=70 degrees and the* **Pit slope***=(maximum) 25 degrees resulting in a* **Face slope** *and* **Pit slope** *expansion.*

Utilizing the **Face slope**, **Pit slope**, and **Berm width** options, found on either the **Required** or **Optional** tab, you can implement simple or complex slopes into a pit design. Understanding how the **Face slope**, **Pit slope**, and **Berm width** values are used and calculated increases the control you have over the expansion of the pit, thus reducing the need to splice crests and toes and providing a more efficient use of the **Pit Expansion** tool.